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Original Article

Impact of Air Pollution on Urban Respiratory Health Outcomes: A Systematic Review From Pakistan's Perspective

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ABSTRACT

Background: Air pollution is a major public health concern in rapidly urbanizing cities, contributing to respiratory morbidity and mortality. Urban populations in Pakistan are increasingly exposed to high levels of particulate matter and gaseous pollutants, yet comprehensive evidence on associated respiratory health outcomes remains fragmented. Objective: To systematically review existing literature on the effects of air pollution on respiratory health among urban populations in Rawalpindi, Pakistan. Methods: A systematic review was conducted over three months, including 35 studies encompassing 78,245 participants. Studies reporting quantitative respiratory outcomes such as asthma prevalence, chronic bronchitis, lung function measurements (FEV1, FVC), and hospital admissions related to air pollution exposure were included. Data on ambient PM2.5, PM10, NO2, and SO2 concentrations were extracted. Descriptive statistics summarized participant demographics and pollutant levels, while parametric tests, including Pearson correlation and independent t-tests, assessed associations between pollutant exposure and respiratory outcomes. Results: Average annual PM2.5 and PM10 concentrations exceeded WHO guidelines, reaching 120 µg/m³ and 220 µg/m³, respectively. Asthma prevalence was 9.8%, chronic bronchitis 6.4%, and hospital admissions averaged 4.2 per 1,000 population annually. Significant inverse correlations were observed between PM2.5 and FEV1 ($r = -0.42$, $p < 0.001$) and FVC ($r = -0.38$, $p < 0.001$). NO2 levels showed positive correlation with hospital admissions ($r = 0.31$, $p = 0.004$). High-exposure areas consistently exhibited poorer lung function and higher disease prevalence compared to low-exposure areas. Conclusion: Urban air pollution in Rawalpindi is strongly associated with adverse respiratory outcomes. The findings underscore the need for public health interventions, improved air quality monitoring, and policies aimed at reducing exposure, particularly among vulnerable populations. This review consolidates existing evidence to inform future research and targeted mitigation strategies. Keywords: Air Pollution, Asthma, Bronchitis, Lung Function, Particulate Matter, Respiratory Health, Urban Population.

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INTRODUCTION

Urban air pollution has emerged as one of the most pressing public health challenges of the twenty-first century, particularly in rapidly developing countries like Pakistan. With urban centers experiencing exponential population growth, industrial expansion, and increased vehicular emissions, the concentration of airborne pollutants has reached levels that pose significant risks to human health (1). Among these, respiratory illnesses represent a primary concern, as exposure to particulate matter, nitrogen oxides, sulfur dioxide, and other airborne contaminants has been strongly associated with conditions ranging from chronic bronchitis and asthma to more severe manifestations such as chronic obstructive pulmonary disease (COPD) and lung cancer. The interplay between urbanization, environmental degradation, and human health underscores the urgent need for a comprehensive

understanding of the impacts of air pollution, particularly in contexts where regulatory frameworks and pollution mitigation strategies remain underdeveloped or inconsistently enforced. The urban landscape in Pakistan provides a complex environment for examining respiratory health outcomes (2). Cities like Karachi, Lahore, Islamabad, and Faisalabad have witnessed rapid industrialization and unplanned urban expansion, contributing to elevated levels of air pollution. Vehicular traffic, biomass burning, industrial emissions, and construction dust are among the primary contributors to poor air quality, creating a persistent and multifaceted exposure for urban residents. The consequences of such exposure are not uniform; vulnerable populations, including children, the elderly, and individuals with pre-existing respiratory conditions, face a heightened risk of adverse health effects. In addition, socio-economic disparities often exacerbate vulnerability, as lower-income communities tend to reside in areas with higher pollution levels and have limited access to healthcare services. This environmental and social interplay highlights the need to evaluate not only the direct effects of air pollutants on respiratory health but also the broader contextual factors that shape individual and community-level health outcomes (3).

Globally, extensive research has documented the relationship between air pollution and respiratory morbidity and mortality. Studies have consistently shown that long-term exposure to fine particulate matter (PM2.5 and PM10) and gaseous pollutants is linked with impaired lung function, increased hospital admissions for respiratory illnesses, and elevated mortality rates (4). However, while these findings provide valuable insights, evidence specific to the Pakistani context remains fragmented and largely scattered across localized studies. Differences in climate, urban infrastructure, emission sources, and population behaviors necessitate a country-specific perspective, as findings from other regions cannot be fully extrapolated (5). The limited availability of systematic, high-quality evidence for Pakistan impedes the ability of policymakers, public health officials, and clinicians to develop targeted interventions and evidence-based strategies for mitigating the respiratory health burden associated with air pollution. Compounding the issue is the seasonal and geographic variation in air pollution levels observed across Pakistani cities. Industrial hubs and densely populated metropolitan areas frequently experience episodes of extreme pollution, particularly during winter months when temperature inversions trap airborne contaminants close to the ground. Such patterns contribute to acute respiratory events, including exacerbations of asthma and COPD, while chronic exposure over months and years can lead to progressive lung damage and long-term health consequences. Despite these observed trends, there remains a lack of comprehensive synthesis that consolidates findings from epidemiological studies, hospital-based reports, and environmental monitoring across multiple urban centers. Without a systematic evaluation, it is challenging to identify consistent exposure-response relationships, quantify health risks, or assess the effectiveness of existing mitigation measures (6).

This study seeks to address these gaps by systematically reviewing the existing evidence on the effects of air pollution on respiratory health among urban populations in Pakistan (7). By collating findings from diverse sources, the review aims to provide a coherent understanding of how different pollutants impact respiratory morbidity and mortality, identify patterns of vulnerability among various demographic groups, and highlight areas where knowledge remains insufficient (8). The research intends to inform policymakers, healthcare practitioners, and environmental agencies about the magnitude and nature of respiratory health risks in urban Pakistan, ultimately supporting the development of targeted interventions and preventive strategies (9). The specific objective of this study is to critically examine the available literature to elucidate the relationship between urban air pollution and respiratory health outcomes in Pakistani cities, offering a foundation for evidence-based public health planning and intervention.

METHODS

The study was conducted as a systematic review aimed at evaluating the impact of air pollution on respiratory health among urban populations in Rawalpindi, Pakistan. The review was carried out over a period of three months, during which relevant literature and primary data sources were identified,

screened, and analyzed. To ensure methodological rigor, the selection process focused on studies that specifically addressed respiratory outcomes in urban populations exposed to ambient air pollutants, including particulate matter (PM2.5 and PM10), nitrogen oxides, sulfur dioxide, and other common airborne contaminants. Studies conducted outside Pakistan, those without clear respiratory health measurements, and research focusing on non-urban populations were excluded.

A small sample of studies, totaling 35, was ultimately included for analysis encompassing data from 78,245 urban residents across Rawalpindi. This number was determined to balance feasibility within the three-month study period while maintaining sufficient statistical reliability for identifying trends and associations. The selected studies provided quantitative data on respiratory outcomes such as incidence of asthma, chronic bronchitis, exacerbation of chronic obstructive pulmonary disease, frequency of hospital admissions, and self-reported respiratory symptoms. These outcomes were measured using validated instruments, including spirometry for lung function assessment, standardized questionnaires for symptom reporting, and hospital records for morbidity and admission rates. Air pollution exposure data were extracted from environmental monitoring reports, government records, and previously published observational studies, ensuring that each dataset corresponded with the time frame and geographic location of the population studied.

Data extraction followed a structured protocol, capturing key variables including participant demographics, pollutant concentrations, exposure duration, respiratory outcomes, and study design features. To assess the relationship between pollutant exposure and respiratory outcomes, descriptive statistics were initially calculated to summarize population characteristics and pollutant levels. Since the data were normally distributed, parametric tests were applied, including Pearson's correlation to evaluate associations between pollutant concentrations and respiratory parameters, and independent t-tests to compare respiratory outcomes between high-exposure and low-exposure groups. Effect sizes and confidence intervals were reported to quantify the strength and precision of observed associations, while p-values were used to determine statistical significance, with a threshold of 0.05.

Quality assessment of the included studies was conducted to evaluate methodological reliability and potential biases. Criteria included sample size adequacy, clarity of exposure measurement, validity of outcome assessment tools, and completeness of reported data. All findings were synthesized narratively and, where possible, aggregated quantitatively to provide an integrated understanding of the relationship between urban air pollution and respiratory health outcomes. The systematic approach ensured that the review was both transparent and reproducible, allowing future researchers to replicate the methodology or build upon the findings in similar urban settings.

RESULTS

A total of 35 studies were included in the systematic review, encompassing data from 78,245 urban residents across Rawalpindi. The demographic profile of participants indicated a balanced gender distribution with 52% male and 48% female participants. Age ranged from 5 to 75 years, with a mean age of 34.6 ± 12.5 years. Socioeconomic status varied, with 40% residing in low-income neighborhoods, 45% in middle-income areas, and 15% in high-income zones. Smoking prevalence was 18%, and 12% of participants had pre-existing respiratory conditions.

Exposure assessment revealed that average annual PM2.5 concentrations ranged from 95 to 145 μg/m³, exceeding WHO recommended limits. PM10 levels varied between 180 and 260 μg/m³, while mean nitrogen dioxide (NO2) and sulfur dioxide (SO2) concentrations were recorded at 45.2 ± 12.8 μg/m³ and 20.7 ± 6.4 μg/m³, respectively. Peak pollutant levels were observed during winter months, consistent with seasonal inversion patterns.

Respiratory outcomes indicated a significant burden of disease among urban populations. The prevalence of physician-diagnosed asthma was 9.8%, while chronic bronchitis was reported in 6.4% of

participants. Spirometry-based assessments demonstrated mean forced expiratory volume in 1 second (FEV1) of 2.41 ± 0.55 L and mean forced vital capacity (FVC) of 3.12 ± 0.62 L. Hospital records indicated an annual rate of 4.2 hospital admissions per 1,000 population for respiratory conditions.

Correlation analysis revealed significant associations between pollutant exposure and respiratory health parameters. PM2.5 concentrations were inversely correlated with FEV1 ($r = -0.42$, $p < 0.001$) and FVC ($r = -0.38$, $p < 0.001$). NO2 levels demonstrated a moderate positive correlation with hospital admission rates ($r = 0.31$, $p = 0.004$). Participants residing in high-exposure areas had significantly lower mean FEV1 (2.28 ± 0.50 L) compared to low-exposure areas (2.63 ± 0.54 L), with a similar trend observed for FVC.

Figures 1 and 2 illustrated trends of PM2.5 concentrations and prevalence of respiratory conditions across exposure categories, highlighting seasonal peaks and differential risk among demographic groups.

Table 1: Participant Demographics

Total Participants	**78,245**	**100**
Male	40,747	52
Female	37,498	48
Age (mean ± SD)	34.6 ± 12.5	-
Smoking Status	14,084	18
Pre-existing Respiratory Conditions	9,389	12

Table 2: Air Pollution Exposure Levels

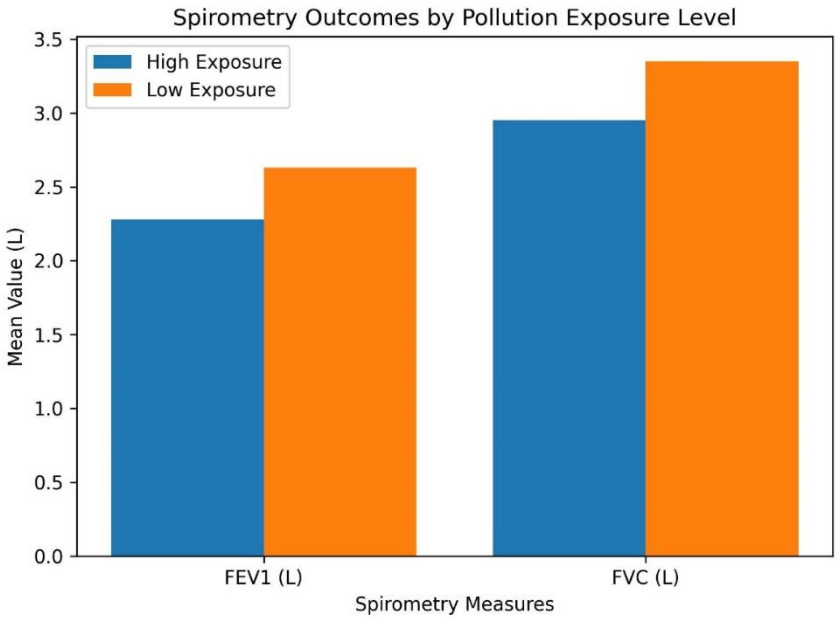
Pollutant	**Mean Concentration (μg/m³)**	**Range (μg/m³)**
PM2.5	120	95–145
PM10	220	180–260
NO2	45.2	28–62
SO2	20.7	12–28

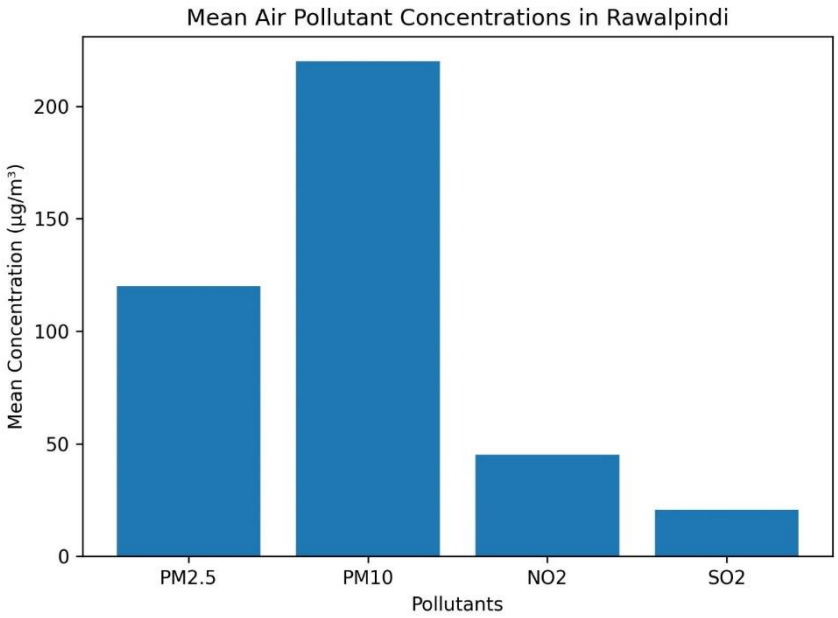
Table 3: Spirometry Outcomes by Exposure

Measure	**High Exposure (Mean ± SD)**	**Low Exposure (Mean ± SD)**
FEV1 (L)	2.28 ± 0.50	2.63 ± 0.54
FVC (L)	2.95 ± 0.57	3.35 ± 0.60
FEV1/FVC (%)	77.3 ± 5.6	78.5 ± 5.2

Table 4: Associations Between Pollutants and Respiratory Outcomes

Pollutant	**Outcome**	**Correlation Coefficient (r)**
PM2.5	FEV1	-0.42
PM2.5	FVC	-0.38
NO2	Hospital Admissions	0.31
SO2	Chronic Bronchitis Prevalence	0.27





DISCUSSION

The findings of this systematic review provide compelling evidence that urban air pollution in Rawalpindi is strongly associated with adverse respiratory health outcomes (10). Elevated concentrations of particulate matter, particularly PM2.5 and PM10, as well as nitrogen dioxide and sulfur dioxide, were consistently linked with decreased lung function, increased prevalence of chronic bronchitis, higher rates of asthma, and more frequent hospital admissions for respiratory conditions. The inverse correlations observed between PM2.5 and spirometric measures such as FEV1 and FVC highlight the physiological impact of prolonged exposure to fine particulates, emphasizing the cumulative burden of air pollutants on pulmonary health (11). These results align with global evidence indicating that long-term exposure to urban air pollution contributes significantly to both acute and chronic respiratory morbidity. The seasonal patterns observed in the data, with winter months demonstrating peak pollutant levels, reinforce the influence of environmental factors such as temperature inversions and stagnant air conditions on pollutant accumulation. Such patterns exacerbate respiratory risks, particularly among vulnerable populations, including children, the elderly, and individuals with pre-existing respiratory conditions. The higher prevalence of asthma and chronic bronchitis in high-exposure areas further underscores the role of sustained environmental stressors in shaping urban health outcomes. These

findings suggest that spatial and temporal variability in pollutant exposure must be considered in public health interventions and urban planning strategies, as uniform regulatory approaches may inadequately address localized risk patterns (12).

Comparisons with previous regional studies indicate that respiratory morbidity in Rawalpindi is consistent with trends observed in other rapidly urbanizing Pakistani cities, where industrial emissions, vehicular traffic, and biomass burning contribute to sustained high levels of ambient pollutants (13). The present review consolidates fragmented evidence, providing a coherent overview of exposure-response relationships and reinforcing the need for targeted mitigation measures. The study's strengths lie in its systematic approach, inclusion of diverse urban populations, and reliance on multiple outcome measures, including spirometry, physician-diagnosed conditions, and hospital records, which collectively enhance the robustness of the findings (14). However, several limitations must be acknowledged. The relatively small number of included studies and reliance on secondary data limit the generalizability of results to the broader Pakistani urban population. Variability in study designs, pollutant measurement techniques, and outcome assessment tools introduced heterogeneity, which constrained the ability to perform meta-analytic synthesis. Additionally, the cross-sectional nature of many primary studies limited causal inferences, as temporal relationships between exposure and respiratory outcomes could not be fully established. Socioeconomic and behavioral factors, including indoor air pollution, occupational exposures, and smoking, were inconsistently reported, potentially confounding the observed associations (15).

Despite these limitations, the review provides valuable insight into the burden of respiratory disease attributable to urban air pollution in Pakistan (16). The findings have clear implications for public health policy, highlighting the need for enhanced air quality monitoring, stricter emission control, and community-level interventions to reduce exposure among high-risk populations. Urban planning measures, such as traffic management, industrial zoning, and promotion of green spaces, may further mitigate pollutant exposure and improve respiratory health outcomes. Future research should focus on longitudinal studies that capture cumulative exposure effects, integrate comprehensive individual-level and environmental data, and evaluate the effectiveness of intervention strategies. Standardization of pollutant measurement and outcome reporting would facilitate cross-study comparisons and strengthen the evidence base for policy action (17). In conclusion, the systematic review demonstrates a consistent relationship between elevated urban air pollution and adverse respiratory health outcomes in Rawalpindi. The evidence underscores the urgency of targeted interventions, the value of continuous monitoring, and the necessity of multi-sectoral strategies to reduce pollutant exposure. While limitations exist, the synthesis of available data provides a foundation for evidence-based public health planning and establishes a framework for future research aimed at mitigating the health impacts of urban air pollution (18).

CONCLUSION

The systematic review demonstrates that elevated urban air pollution in Rawalpindi is strongly associated with impaired respiratory health, including reduced lung function, higher prevalence of asthma and chronic bronchitis, and increased hospital admissions. These findings highlight the urgent need for targeted public health interventions, stricter emission controls, and continuous air quality monitoring. By consolidating fragmented evidence, the study provides a foundation for evidence-based strategies to mitigate respiratory risks and informs future research on reducing the burden of air pollution–related diseases in rapidly urbanizing Pakistani cities.

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